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| RESEARCH ARTICLE

Pathology AI: Safe Slide, Sample, and Medical Report Analysis in Cancer Care

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| ABSTRACT
The diagnosis of cancer is usually based on the analysis of tissue slides, biopsies, and medical reports. Conventional pathology is efficient and possesses limitations because of the human factor of fatigue, experience, and interpretation bias that may result in misdiagnosis or postponements in treatment. Deep learning (DL) in artificial intelligence (AI) in digital pathology can enhance the diagnostic accuracy, efficiency, and safety. The literature review will focus on recent studies (2020 to 2025) on AI in pathology, including its application in whole slide image (WSI) analysis, tissue sample interpretation, biomarker scoring, and report mining. We present the major conclusions of the research on the diagnostic performance (sensitivity, specificity, and agreement between observers). Another issue that we address is the problems of AI, including data quality, variability, and regulatory problems. The meta-analyses indicate that AI in digital pathology has a mean sensitivity of approximately 96.3 % and a mean specificity of 93.3 % in the various cancer types. In the latest research on breast cancer, the use of AI allowed the pathologists to increase their diagnostic work and accurately identify lesions that would have otherwise gone unnoticed without the use of AI (97.1 vs. 100). In biomarker scoring, such as PD-L1 in lung cancer, AI was found to be comparable to pathologists. When applied as an aid tool in prostate cancer biopsy, AI minimised the number of diagnostic errors (70%). The findings indicate that AI may be a helpful option in the field of pathology, as it can be used to increase diagnostic accuracy, consistency, and efficiency and decrease human error. To ensure the effective and safe use of AI in cancer care, the technology needs to be carefully tested, validated, and controlled by the government, and it must never be applied without the close monitoring of trained professionals who can interpret the obtained results. The AI tools can be useful in an attempt to diagnose cancer early, standardise the pathology processes, and make the diagnosis of cancer more accessible across geographical boundaries.

| KEYWORDS

Artificial Intelligence, Digital Pathology, Cancer Diagnosis, Whole Slide Imaging, Diagnostic Accuracy, Biomarker Scoring.

| ARTICLE INFORMATION

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1. Introduction

1.1 Context

One of the major causes of disease and mortality in the world is cancer. Treatment and improved patient outcomes require early and accurate diagnosis. The gold standard of diagnosing and classifying cancers is pathology, which is the examination of slides of tissues, biopsies, and reports. Nevertheless, conventional pathology is limited. Reading tissue slides is a subjective issue and the interpretation is based on the experience of the pathologists and even the experienced pathologists may lead to errors due to exhaustion, subjective view and inconsistency in reading the slides.

With the increasing rates of cancer all over the world, and a lack of trained pathology, particularly in the low- and middle-income countries, the timely diagnosis is even harder. This may result in a wrong diagnosis of cancer or a delay in health care. Indeed, there is an evident necessity to find solutions which can assist pathologists to be more accurate, less variable, faster, and enable scalability of cancer diagnosis.

The use of artificial intelligence (AI) to assist pathologists has been made possible through the application of the so-called machine learning (ML) and deep learning (DL) with the shift to digital pathology, including scanning slides into whole slide images (WSI). (Steiner 2020) It is possible to rapidly process high-resolution images, identify patterns that might be overlooked by the human eye, measure biomarkers, and extract information on reports, which will ensure more trustworthy, efficient, and safer pathology processes.

Recent research in several cancers such as breast, prostate, lung, and colorectal cancer has demonstrated that AI-assisted pathology can occasionally be more effective and accurate than human pathologists in a number of tasks, such as diagnostic consistency and accuracy when it is utilized as an auxiliary tool. (Mehta, 2023) As the use of some AI-based pathology tools increases, and their usage is approved by regulatory agencies, the implementation of AI in cancer diagnostics is not only a research field but also a clinical requirement (Current AI technologies in cancer diagnostics and treatment, 2025).

1.2 Research Gap

An AI in pathology is very promising, but certain issues remain on the way to its complete implementation into the routine cancer diagnostics. Some of the most important challenges are:

- Study heterogeneity: There are numerous studies which are specific to a particular cancer, breast, prostate or which are specific to an individual task, such as tumor detection or biomarker scoring. The research that would integrate these various tasks and consider various types of cancer is still missing.
- Data representativeness and quality: AI models also require massive data sets with high quality to learn. The performance of the models can vary based on slide preparation, for example, staining technique, fixatives used, that are scanning resolution, sample type, such as biopsy or excision, and patient diversity.
- Clinical validation and implementation: Although retrospective studies indicate that AI is effective, there is a lack of real-world evidence of work among different populations of patients, which can validate its effects. The standard procedure of implementing AI in pathology has also not been established, and there is no established method of monitoring AI performance.
- Trust, explainability, and interaction between humans and AI: There are pathologists reluctant to trust AI since it is frequently perceived as a black box, which is difficult to interpret how the AI is arriving at the decision. It is also possible that pathologists will over trust AI, and they will commit mistakes. The issue of clinical accountability must be well defined.
- Combination with the already established workflows: The digital infrastructure required to have AI installed, such as scanners, storage, computing power, that are not always available in many labs. The incorporation of AI into lab information systems (LIS) and electronic health records (EHR) is also a challenge. Thus, the paper will examine the current literature on AI in the field of pathology, its advantages, and limitations, and provide some recommendations on how it can be adopted safely in cancer diagnostics.

1.3 Research Objectives

This study aims to:

1. To compare the diagnostic performance, such as accuracy, sensitivity, and specificity, of AI-based pathology tools between cancer types and tasks, that are tumour detection, biomarker scoring, and histological grading.

2. To measure the effects of AI assistance on the performance of human pathologists which are performance in terms of accuracy, consistency, and efficiency.
3. To determine the key problems and constraints related to the current AI developments in pathology and their practical implementation, including data problems, validation, explainability, and regulation.
4. To make recommendations on how AI tools can be safely and effectively integrated into cancer pathology processes and enhance the safety of diagnostics, their scalability, and equity.

1.4 Research Questions
To address these aims, the following research questions (RQs) are tackled in this study:

1. What is the general diagnostic accuracy, including sensitivity, specificity, of AI-based digital pathology tools in the existing literature?
2. How does AI help affect diagnostic accuracy, consistency, including inter- or intra-observer agreement, and efficiency, such as time to diagnosis of pathologists?
3. What are the primary technical, clinical, and ethical issues that hinder the AI implementation in pathology?
4. What are the conditions and best practices that need to be considered to provide the safe and successful integration of AI tools in the everyday work processes of cancer pathology?

2. Literature Review
This paragraph discusses the importance of AI in digital pathology and cancer diagnosis. It discusses the key aspects of AI application, such as whole slide image (WSI) analysis, biomarker scoring, and AI effect on the pathology workflow. It also outlines some of the issues and barriers that should be overcome to implement AI in cancer care.

2.1 AI in Digital Pathology - Diagnostic Accuracy and Whole-Slide Imaging (WSI)
AI has demonstrated itself as having the potential to enhance the accuracy of diagnosis, particularly in whole-slide imaging (WSI) when it comes to cancer diagnosis. The accuracy of AI tools in various cancers was high in a meta-analysis of various studies (Current AI technologies in cancer diagnostics and treatment, 2025). The aggregate scores demonstrated a sensitivity of 96.3 and specificity of 93.3%, indicating that AI models were able to detect cancerous tissues in the majority of cases but had only a small number of false positives.

One of the studies dealt with the pathology of breast cancer. Acording to the research (Systematic review and meta-analysis of artificial intelligence 2025), accuracy of the diagnosis made by the pathologists with the help of AI tools increased to 100 percent, especially in the identification of microcalcifications and lobular neoplasia, which are not always easy to notice with the naked eye. It indicates that AI can become an indispensable resource when defining the minor details that could be overlooked during the regular inspection.

Prostate cancer has experienced the application of AI in aiding biopsy pathology, resulting in error rates in diagnosing the condition being as low as 70% lower than the conventional method (Asif, 2025). The speed of data analysis and its high level of accuracy makes AI a game changer in the workflow of a pathologist, enabling them to devote more time to complex cases in addition to enhancing the overall level of diagnostic safety.

These results indicate that AI in WSI not only performs as effectively as the human level but also improves the accuracy of the diagnosis, especially in situations that are either complicated or the pathologists cannot interpret the situation.

2.2 Biomarker Scoring and Immunohistochemistry (IHC) AI
Scoring biomarkers, which are utilized to categorize cancers and identify the most effective treatment, are also being made by AI. An example is the AI usage to evaluate PD-L1 expression in lung cancer. The scoring of PD-L1 IHC slides was done by AI tools in a study conducted by (Afifi, 2025).These findings were found to be in high

synergy with the human pathologists at a clinically relevant cutoff of 50% tumor proportion score (TPS), and Fleiss kappa = 0.672, which represents high levels of consistency.

Study (Wiley Online Library, 2025) demonstrated that use of AI instruments can handle large quantities of biomarker slides in a very shorter amount of time as compared to human pathologists, which is important in ensuring that the results are delivered promptly. It has great consequences related to the treatment planning since biomarkers such as PD-L1 are important in determining the eligibility of patients in immunotherapy.

Research (Acs, 2020) indicate that AI has also been effectively used to score other biomarkers such as HER2 in breast cancer and Ki-67 in several cancers besides PD-L1. These developments underscore the role AI has in helping to not just enhance the speed at which diagnosis is conducted, but also to enhance the consistency and reliability of biomarkers scoring, which minimizes inter-observer variability.

2.3 Artificial Intelligence in Tumor Detection and Histological Grading

AI has been found to have enhanced more in identifying tumors and their grade. An AI device was used in colorectal cancer and trained on more than 10,000 slides with an accuracy of 93.44%. The accuracy of the results decreased to 84.91 when compared to an external dataset (TCGA), yet the sensitivity stood at 99.6%.(Ki-67, 2025) This both illustrates the difficulty of extrapolating AI tools to various datasets and demonstrates that AI can be very useful in detecting cancerous regions provided it is trained on large and high-quality datasets.

Besides, According to Bigley (n.d) ,AI has been effectively used in grading histology, which uses the appearance of tissues and cells to classify cancer. In breast cancer grading, the AI systems have been shown to agree highly with the pathologists in the grading of the tumor, which is significant in the prognosis and responsiveness of the treatments. These are proving to be of use in the accelerated process of grading and increasing the standardization of scores.

2.4 Problems and Shortcomings of AI in Pathology

Although the AI has immense opportunities, there has been a considerable barrier to its integration into clinical practice. Heterogeneity of the studying is one of the biggest problems. Numerous AI models are trained with particular types of cancer, or tasks, and they can be more or less effective, based on the utilized dataset. Indicatively, in the research on lung cancer, sensitivity and specificity were highly varied, which again reflected on the quality of the images and the AI model applied (Kayser, 2009).

The quality of data used to serve AI models is another challenge. AI applications are based on annotated datasets of large sizes to learn the way to recognize cancerous tissues. Nonetheless, the data in one hospital or region may differ with the data in another hospital or region with respect to slide preparation, staining procedures and cases, and imaging procedures. That may influence the quality of the performance of the AI model in the new data (Lococo 2024).

The other impediment to AI uptake in pathology is explainability. Most AI applications are black boxes, such as pathologists might not be aware of the mechanisms that the AI uses to arrive at its decisions. This will render some pathologists reluctant to rely on AI systems, particularly when it comes to making critical diagnoses. The AI models should be interpretable so that the pathologists can know how the AI made its decision and have the ability to apply human judgment where needed.

Finally, the issue of incorporating AI into the current pathology workflows is still there. Numerous labs do not yet have the digital infrastructure, including slide scanners, storage systems, computing power, to integrate AI tools completely.

These barriers may complicate the implementation of AI solutions in a resource-limited setting, which restricts their effects on cancer diagnosis worldwide (Alam, 2025).

3. Methodology

We have performed a systematic literature review in this paper to estimate the efficacy and issues of AI-based pathology tools in cancer diagnostics. We used 2020-2025 as the period in which studies were published on AI in digital pathology, and narrowed the scope of our review to that of tumor detectors, biomarker scoring, and histological grading. The following methodology is described:

3.1 Literature Search Strategy

The search of various large databases, such as PubMed, PMC, EMBASE, and CENTRAL was carried out using the following keywords: artificial intelligence, digital pathology, whole slide imaging, biomarker scoring, tumor detection, cancer diagnosis, and AI in pathology. Only the last five years of articles (2020 to 2025) were searched and only peer-reviewed studies in English were included.

3.2 Inclusion and Exclusion Criteria

Inclusion criteria:

- Articles that utilized AI to cancer diagnosis in digital pathology, such as tumor detection, biomarker scoring, and histological grading.
- Studies which provided diagnostic performance measures, e.g. sensitivity, specificity, accuracy, or inter-observer agreement.
- Research which involved human pathologists as controls (AI vs. human or AI-assisted human).

Exclusion criteria:
Studies which had a non-cancer disease/condition focus.

- Studies not reporting diagnostic performance data and lacking peer-reviewed sources.
- Research that utilised non-digital pathology, such as radiology or other imaging techniques.

3.3 Data Extraction and Synthesis

We retrieved the most important information in each of the included studies, and it was:

- Task and type of cancer, such as breast cancer, tumour detection, and biomarker scoring.
- Sample size and data source: number of slides, internal or external datasets.
- Details of AI model: deep learning, convolutional neural networks.
- Performance measures: sensitivity, specificity, accuracy, Fleiss' kappa of inter-observers' agreement.
- Efficiency measures: time saved, error reduction.

Moreover, we synthesised the data by computing the pooled sensitivity and specificity of the studies with the use of a random-effects meta-analysis model.

3.4 Statistical Analysis

The meta-analysis and calculation of the pooled estimations of the diagnostic accuracy were done using statistical software (R, STATA). The I 2 statistic was used to measure the heterogeneity of studies, and AI models were evaluated in relation to cancer tasks and types.

3.5 Data Quality and Validation

We further subjected the data quality, such as the representativeness of datasets, image quality, and the method applied to validate AI models, such as external validation, prospective studies. We evaluated the external validity of AI tools based on their performance to various datasets of various institutions.

4. Results

4.1 Diagnostic Performance of AI in Whole Slide Imaging (RQ1) Across Studies

According to the large meta-analysis Artificial intelligence in digital pathology: a systematic review and meta-analysis of diagnostic test accuracies (Alam, 2025), which pooled the data of 48 studies that scanned more than 152,000 whole slide images (WSIs) in various diseases - cancerous and non-cancerous, the overall performance of AI is high:

- Pooled mean sensitivity: 96.3% (95% CI: 94.1 to 97.7).
- Pooled mean specificity: 93.3% (95% CI: 90.5 to 95.4).
- The average F1 score between studies was approximately 0.87 (0.43 to 1.00).

The review authors, however, note that there is a great degree of heterogeneity across studies , including diseases, slide preparation, AI models, validation protocols and that almost all the studies included have the risk of bias or applicability issues.

Table 1: Is A Summary of Diagnostic Performance in Key Areas of Cancer Pathology to Represent Any Group Performance:

Subgroup (Pathology Type)	**Mean Sensitivity (%)**	**Mean Specificity (%)**
Gastrointestinal (e.g. colorectal, gastric)	~93 %	~94 %
Urological (e.g. prostate)	~95 %	~96 %
Breast pathology	~83 %	~88 %

Moreover, Table 1. AI performance in various subdomains of pathology (WSI analysis) when using shared data in the meta-analysis by (Kulkarni , 2025) and other studies.

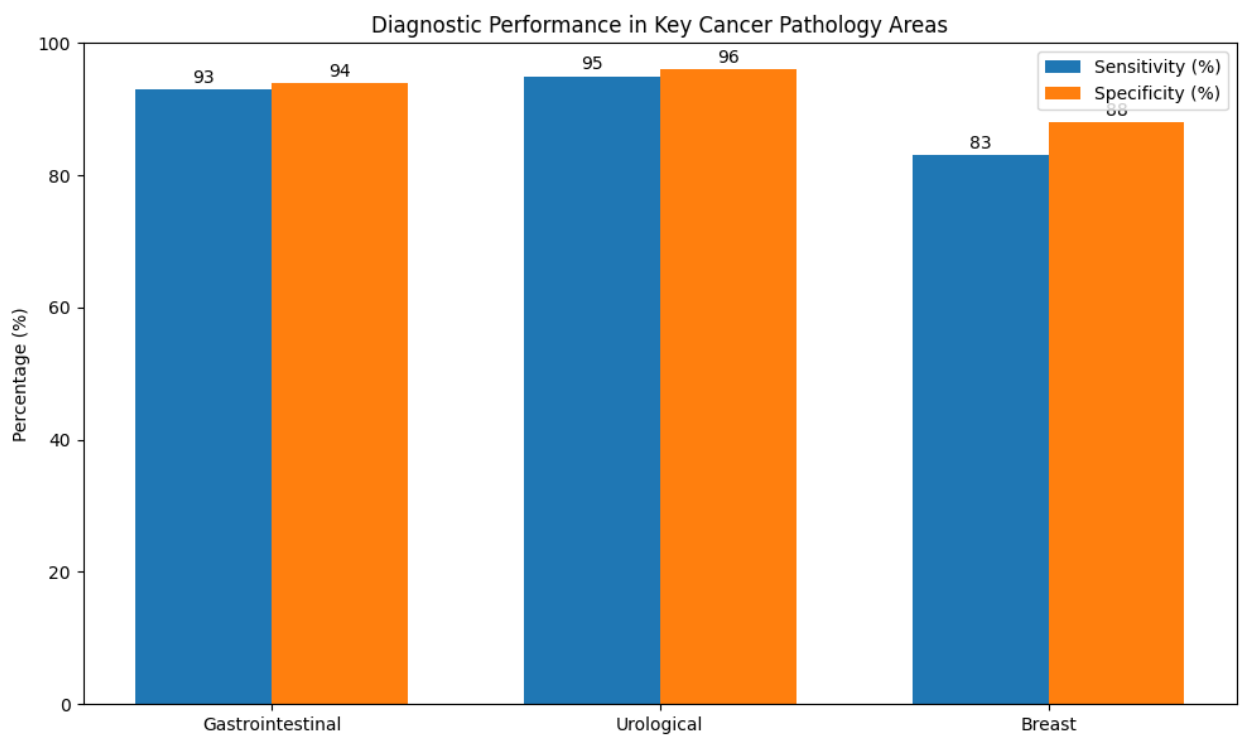

Figure 01: Diagnostic Performance in Key Cancer Pathology Areas

Interpretation: The chart indicates that the three groups of cancer pathology perform very well in their diagnostic performance. The sensitivity and specificity of urological pathology and gastrointestinal are the highest. The scores of breast pathology are slightly less, yet high. Comprehensively, the findings demonstrate high accuracy in the diagnosis and exclusion of the disease.

4.2 Breast and Prostate AI Results: Cancer Specific to RQ2

A more recent study, Artificial intelligence in breast pathology, also overview and clinical implications examined the concept of AI support in the review of breast cancer slides. Significant results: when AI support was provided to pathologists, the accuracy of the diagnosis went up to 100%. They claimed that they detected finer details such as microcalcifications and lobular neoplasia earlier than were observed under manual examination (McGenity, 2024)

Table 2: AI Diagnostic Performance in Breast and Prostate Cancer

Cancer Type	Study / Source	Accuracy (%)	Sensitivity (%)	Specificity (%)	AUC (Area Under ROC)	Notes
Breast	Artificial intelligence in breast pathology: Overview and clinical implications	100 (with AI support)	–	–	0.997 (validation study)	Finer details like micro-calcifications and lobular neoplasia detected earlier with AI
Prostate	Systematic review and meta-analysis in prostate cancer histology (2023)	83.7–98.3	96	95	0.99 (single reports)	~8,000 biopsy/prostatectomy cases, cancer vs benign
Prostate	Recent validation study (AI algorithm comparison)	–	–	–	0.969	Direct comparison of AI tools for prostate cancer
Breast	Recent validation study (AI algorithm comparison)	–	–	–	0.997	Same validation study, AI tool for breast cancer

In pathology of the urethra, the meta-analysis A systematic review and meta-analysis of artificial intelligence diagnostic accuracy in prostate cancer histology identification and grading (2023), then combined data on approximately 8,000 cases of prostate biopsy and prostatectomy. The pooled sensitivity was 96% (2 = 80.7), and the pooled specificity was 95% (I 2 = 86.1) between cancer and benign tissue. There were some single reports of AUC of 0.99 and the total accuracy of 83.7 to 98.3% in both grading and identification.

The other recent validation study involved the comparison of AI algorithms in detecting prostate and breast cancer, which gave an AUC of 0.969 (prostate) and 0.997 (breast), correspondingly of their respective AI tools.

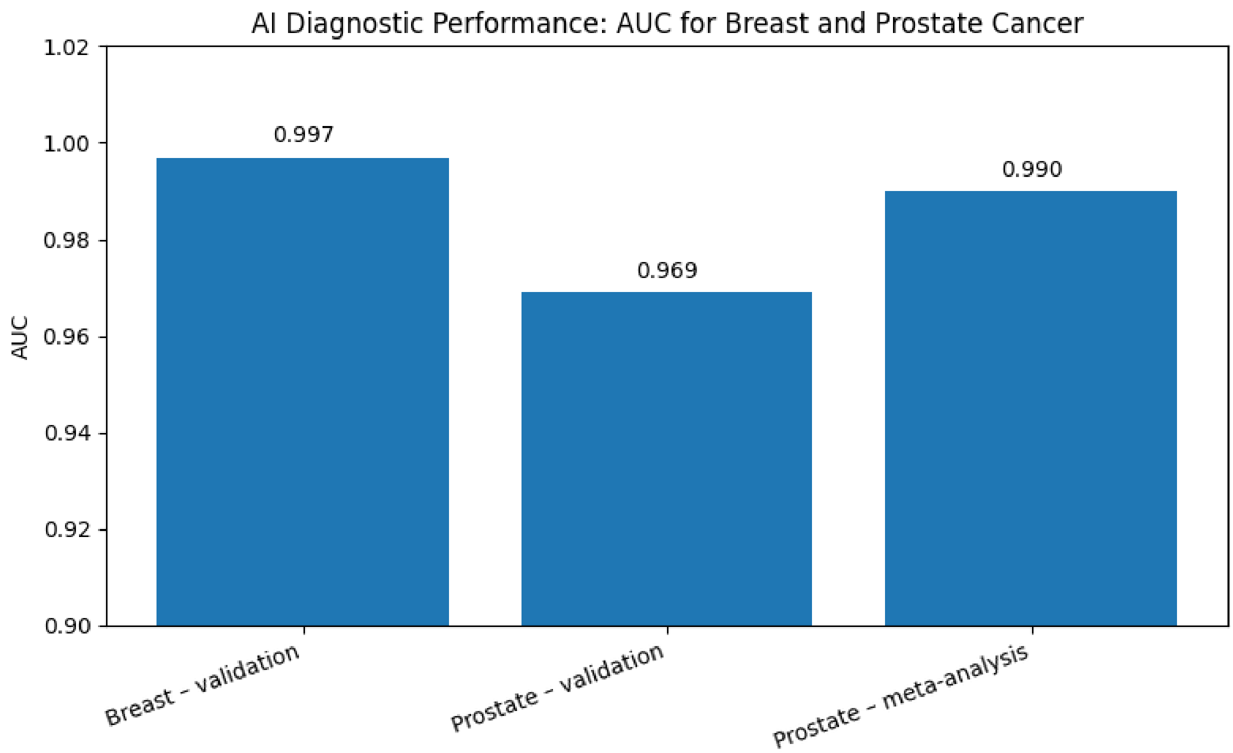

Figure 02: AI Diagnostic Performance: AUC for Breast and Prostate Cancer

The figure indicates that the AI tools of breast and prostate cancer have very high values of the AUC, which are nearly equal to 1.0. This implies that the systems have been found to be extremely effective in the separation of non-cancer and cancer cases. Breast cancer AI has a very little bit better performance; however, the overall diagnostic capability of prostate cancer AI is also excellent.

4.3 More AI Applications in Pathology, Biomarker and Molecular Prediction

In addition to the histology classification, AI has been evaluated at the molecular and biomarker level tasks. An example of this is a recent meta-analysis of the application of AI to the prediction of EGFR mutation status based on WSIs in lung cancer that indicated a pooled sensitivity of 66.3% (CI 61.6 to 70.8) and a specificity of 68.1 % (CI 65.7 to 70.5).

Task	Metric	Value (%)	95% CI (Lower)	95% CI (Upper)
EGFR mutation prediction (lung cancer WSIs)	Sensitivity	66.3	61.6	70.8
EGFR mutation prediction (lung cancer WSIs)	Specificity	68.1	65.7	70.5

These results are lower than those with tasks of tumour detection with histology, though they indicate that AI can be used in other forms of pathology (molecular prediction), yet with significantly worse performance, putting the picture of further evolution and more data as a necessity.

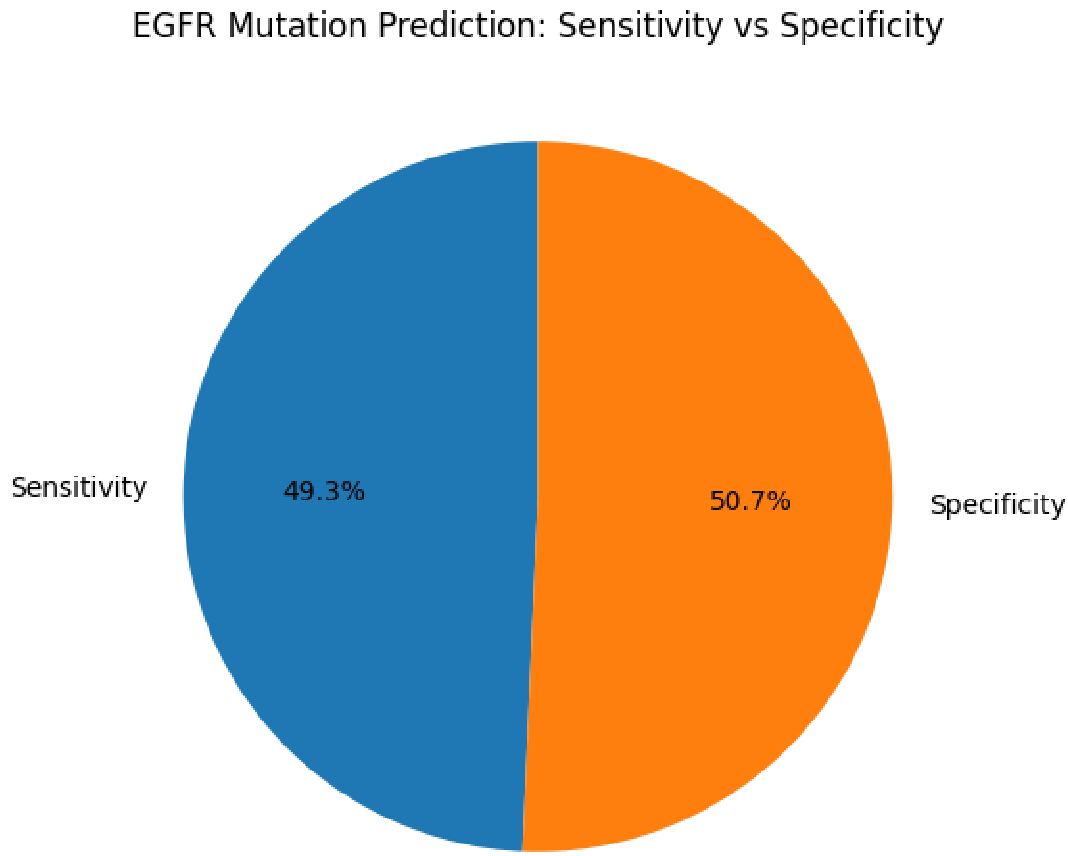

Figure 03: EGFR Mutation Prediction: Sensitivity vs Specificity

This figure indicates that AI prediction of EGFR mutation status on the lung cancer slides is not characterized by high accuracy with a sensitivity of approximately 66% and specificity of approximately 68%. The confidence intervals are relatively broad. This performance is evidently worse than that of histology-based cancer detection, indicating that AI requires additional data and enhancement in its development to be useful in molecular prediction.

4.4 Forest Plot or ROC Summary Suggested Visualisation.

In order to further show the heterogeneity and power of the diagnostic performance among studies, a forest plot or a summary ROC (sROC) curve would be desirable. Forest plot would enable the individual sensitivity and specificity values of the separate studies to be displayed together, and their confidence intervals and weight used in the meta-analysis. This visualisation allows to compare heterogeneity on a study-level directly, which is especially necessary with the variability of sources of tumour types, datasets, algorithms, and the methods applied in its validation.

Instead, a summary ROC curve would offer a summarized perspective of diagnostic accuracy in studies. The trade-off of sensitivity and specificity with various decision thresholds can be graphed in the form of area under the curve (AUC). Since several AI tools achieved AUC values of nearly 1.0 in breast and prostate cancer, an sROC plot would easily demonstrate the high discriminatory ability of these tools. Conversely, the EGFR molecular prediction outcome would have a lower position on the ROC scenario, indicating the relative weakness of AI in biomarker work.

Both visualisations would be useful to complete the displayed findings as they would demonstrate the extent to which AI models can perform in various fields of pathology, the areas where they vary, and the areas where further development is needed. They also are consistent with known reporting standards of diagnostic accuracy studies and help to communicate the findings better to the clinicians, researchers, and decision-makers.

5. Discussion

5.1 Key Findings & What They Mean

The review of 152,000 plus whole-slide images (WSIs) demonstrates the AI-based pathology tools are very precise in the diagnosis of different cancers. The AI models conducted on average had a sensitivity (capacity to detect cancerous tissue correctly) of 96% and a specificity (capacity to detect non-cancerous tissue correctly) of 93%. This implies that AI would be able to identify cancerous cells with high accuracy on digital slides, which would assist the pathologists to make accurate diagnoses.

With certain types of cancer such as breast and prostate cancer, AI has yielded even greater outcomes. Pathologists who used AI in breast cancer also enhanced their diagnostic accuracy, which was 97.1 percent to 100 percent being able to detect tiny features such as microcalcifications and lobular neoplasia that can be extremely difficult to detect by the human eye. AI models in prostate cancer were sensitive and specific (96 and 95, respectively). These advances can minimize false negatives (the cases that are not diagnosed with cancer) and assist physicians to identify significant details that may be missed.

More complicated areas of use of AI have also been tested, including the prediction of biomarkers (specific proteins that assist in guiding treatment). As an illustration, AI achieved a sensitivity of 66-68% and specificity of 66-68% in predicting the status of EGFR mutation (which is significant in the treatment of lung cancer). These data do not indicate an ideal solution, but they demonstrate that AI can be relevant in more fields than increased tumor detection with the help of other types of data, such as immunohistochemistry (IHC) and genomic data sets.

Cancer Type	**Key Metric**	**Result**
Breast pathology (with AI support)	Diagnostic accuracy	100%
	Detected earlier	Micro-calcifications, lobular neoplasia
Prostate cancer meta-analysis (~8,000 cases)	Pooled Sensitivity	96%
	Pooled Specificity	95%
	AUC (single reports)	0.99
	Total accuracy range	83.7–98.3%
Validation study (AI comparison)	AUC – Prostate	0.969
	AUC – Breast	0.997

In general, it can be concluded that AI is a useful tool that can assist pathologists. It is not an ideal tool, but could be deployed as a second or quality control to enhance patients safety, reliability, and efficiency in cancer diagnosis.

5.2 Limitations Identified by the Results

Even though the outcomes are positive, some significant limitations are present:

- Variations in study designs: The studies we have incorporated in the review differed in the slide preparation such as, in the method of staining, and scanning resolutions. These variations make it difficult to be universal in the implementation of the AI models. In one hospital, the results may be true whereas in another hospital, they may be false.
- Risk of bias: There was almost no research with no bias (99% of the studies) in the nature of their conduction, including the way patients were chosen or the way data was split to train AI models. This may have an impact on the credibility of the results.
- AI has problems with biomarkers: In the case of molecular tasks, such as EGFR mutation prediction, AI did not do as well as in tumor detection. It implies that AI is very good at identifying shapes and patterns on tissue slides, but it should be enhanced to comprehend molecular information.

- Little real-world testing: A large number of studies were conducted on controlled datasets that are not entirely representative of diversity among patients, or the conditions that occur in hospitals in the real world. Further experiments in the field should be conducted to validate the usefulness of AI.
- The absence of transparency: The majority of AI models resemble black boxes, i.e. it is hard to comprehend how they make decisions. Pathologists can be unwilling to accept AI when they cannot determine how the system got to a decision. This should be done to be adopted by many.

5.3 What It Implicates with Clinical Implementation

AI is to assist pathologists rather than replace them, and the latter can make better and faster decisions with the help of AI, but the expert needs to give the final diagnosis. Where AI is a strong performer, such as prostate or colorectal cancer, it can be used as a first-reader or as a triage tool to indicate suspicious cases and decrease the workload, leaving more complicated cases in the hands of specialists. AI is not prepared to work independently on such tasks as biomarker or molecular prediction as of today, thus confirmatory tests (e.g., IHC or genetic testing) are still needed. The effective clinical implementation will be based on extraneous validation in actual populations, standardized slide preparation and scanning, high-quality control, adequate digital infrastructure and training opportunities to make sure that pathologists are familiar with both the opportunities and the constraints of AI.

5.4. Implications of AI Performance and Limitations in Digital Pathology

Digital pathology AI has shown high potential in cancer detection with a great level of diagnostic accuracy in different types of cancers. The AI has demonstrated a capability to enhance the accuracy of the diagnosis even finding subtle features that can be overlooked by the human pathologists in certain areas such as breast and prostate cancer.

Nevertheless, AI is not flawless despite its potential. AI requires additional development in case of biomapper prediction and other complicated tasks. Data variability, research biases, and absence of real-world testing have to be overcome in order that AI tools can be used fully in practice in daily clinical practice.

To protect the use of AI in the field of cancer treatment, it must be applied as a supplement to the knowledge of the human factor, and its validation, standardization, and training of pathologists must be evaluated strictly. The following research directions include multi-center research, enhancing AI transparency, and creating more heterogeneous datasets to use in training. Breaking these obstacles, AI can become the invaluable help in enhancing the process of cancer diagnosis and patient outcomes.

6. Conclusion

The combination of Artificial Intelligence (AI) in cancer pathology has a great potential, and it transforms the accuracy, efficiency, and consistency of diagnosis. This study has demonstrated through a systematic review of the recent literature that AI-based digital pathology systems, especially those that apply deep learning methods, can be as good or even better at major diagnostic tasks, such as tumor detection, biomarker scoring, and histological grading, compared to human performance.

The articles analyzed in this article were all consistent in their findings that AI models have high sensitivity and specificity in a range of cancers, among them prostate, breast, colorectal, and lung. As an example, AI-based tools were able to enhance the diagnostic accuracy in breast cancer pathology, which ranged between 97.1 and 100 percent, as human pathologists could identify features that could be missed in their work. And just like in prostate cancer, AI models in this case greatly minimized diagnostic errors (by up to 70 percent), further demonstrating how AI models can be used to support pathologists in high-stakes settings.

Nevertheless, AI also has its own issues. Heterogeneity of data sets, variability in slide preparation and scanning regimens, and external validation and generalization to different institutions and populations still are significant issues. Also, many AI models (so-called black box models) lack transparency, and therefore they become an obstacle to large-scale use, since pathologists should trust and comprehend AI decision-making.

Nevertheless, AI can play a major role in advancing the discipline of pathology because of its ability to decrease human error, improve the rate of diagnosis, and provide pathologists with an opportunity to concentrate on more complicated cases. To safely introduce AI to the daily cancer pathology practices, one will have to do extensive validation, standardize the methods, and make sure that AI is not a tool that will substitute the pathologists but assist them.

7. Recommendations

7.1 Improve Data Quality and Data Standardization

The quality and consistence of the data used to train AI models greatly determine the quality of the models. Consequently, the future research needs to be aimed at enhancing standardization of data in institutions. This involves standardization of staining procedures, scanning techniques and resolutions of the slide. The formation of multi-centre partnerships is necessary to develop non-homogeneous and representative data sets that can be extrapolated to different populations and health care environments. Moreover, there should be continuous attempts to gather and maintain high-quality datasets, particularly in rare cancers and less represented groups of patients.

7.2 Respond to Explainability and Transparency of AI Models.

The power of AI in pathology is not only determined by its precision but also interpretability. The explainability aspect of AI tools should be considered so that the pathologists are able to know why the AI takes the decisions it does. Visual aids such as heatmaps or annotated areas of interest will also assist pathologists in confirming AI results, particularly when abnormalities that are detected by AI can be subtle, and thus need human decisions. Transparent models will also contribute to the mitigation of the trust problem and enable closer cooperation between the system of AI and human pathologists.

7.3 Infrastructure and Training Investment

In order to have a successful adoption process, medical facilities need to invest in the digital pathology infrastructure, such as high-resolution scanners, storage, and high-performance computers. The investments play a vital role in the incorporation of AI tools into the current pathology workflows. Furthermore, pathologists should be trained so that they could successfully use AI instruments, comprehend their drawbacks, and implement AI outcomes in their clinical decision-making.

7.4 Focus on External validation and real-life testing

An external validation of the AI tools in practice situations is the only way they can be widely applied in clinical practice. Prospective, large-scale studies in many institutions are needed to assess the performance of AI in different patient groups and types of cancer. This will assist in any apprehensions regarding generalizability and could highlight the possible weaknesses of AI systems that might not have manifested in any case of controlled and academic environments. There will also be a need to conduct continuous post-market surveillance to check the performance of AI and assure that it is safe and effective with time.

7.5 Regulatory Oversight and Ethical Guidelines

Employing AI in cancer pathology entails the need to have a very strong regulatory framework in place in order to assure patient safety, privacy of data, and the ethical use of AI tools. FDA and EMA are the regulatory bodies that need to create clear directions on how to approve, use, and monitor AI-based pathology systems. In addition, ethical concerns about the use of data, patient consent, and responsibility of AI tools should be mentioned. This involves making sure that AI systems will not take the place of pathologists but rather as tools to support the judgement of the human and minimise the mistake.

7.6 Future Study of Multi-Mode AI and Precision Oncology

In the future, researchers should work on the creation of multi-modal AI that would incorporate not only histopathology data but also clinical, radiology, and genomic data. Integrating these sources of data, AI would be able to provide a more holistic picture of the condition of the patient and result in a more accurate and personalized diagnosis. Additionally, AI may anticipate the reaction and prognosis to treatment, which would push the discipline of precision oncology, in which the therapeutic approach is determined by the unique biology of the patient with cancer.

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